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Renishaw probing technology and the new OMP400 probe featuring strain gauge technology in an ultra compact design

Abstract

Since the invention of the touch trigger probe by Sir David McMurtry in 1972, probing has become a vital component of automated production processes on machine tools. This simple mechanism, employing a kinematic location to retain a stylus in a highly repeatable manner, has formed the basis of many Renishaw probes for over 30 years. Renishaw kinematic touch trigger probes continue to serve the manufacturing industry well, remain the market's best selling probing products by far, and are the first choice of the majority of end users and machine tool builders alike. The level of measuring performance and reliability of these probes must not be understated.

Nonetheless, Renishaw saw an opportunity for improving the accuracy of touch probes for machine tools, leading to the development and marketing of the Renishaw MP700. The introduction of strain gauge sensing has given an increasing number of users the benefits of high accuracy measurement.

Renishaw has now further developed strain gauge technology further with the introduction of the OMP400 touch probe, achieving a high level of measuring performance in a small package.

The kinematic probe

The Renishaw touch trigger probe mechanism (fig. 1) is based on a spring-loaded kinematic arrangement of rods and balls. These provide six points of contact, ensuring that the stylus carrier is held in a unique location with excellent repeatability. The mechanism allows the probe's stylus to be deflected as it contacts the surface of the part, while the spring ensures that the mechanism re-seats when the stylus is in free space. This has been the basis of Renishaw's touch trigger probes for many years, and in some cases, this long history is acknowledged by the fact that they could be referred to as "traditional" probes by some. However, under no circumstances should this description be held as an indication that this mechanism has not seen development over the years and is limited in its performance.

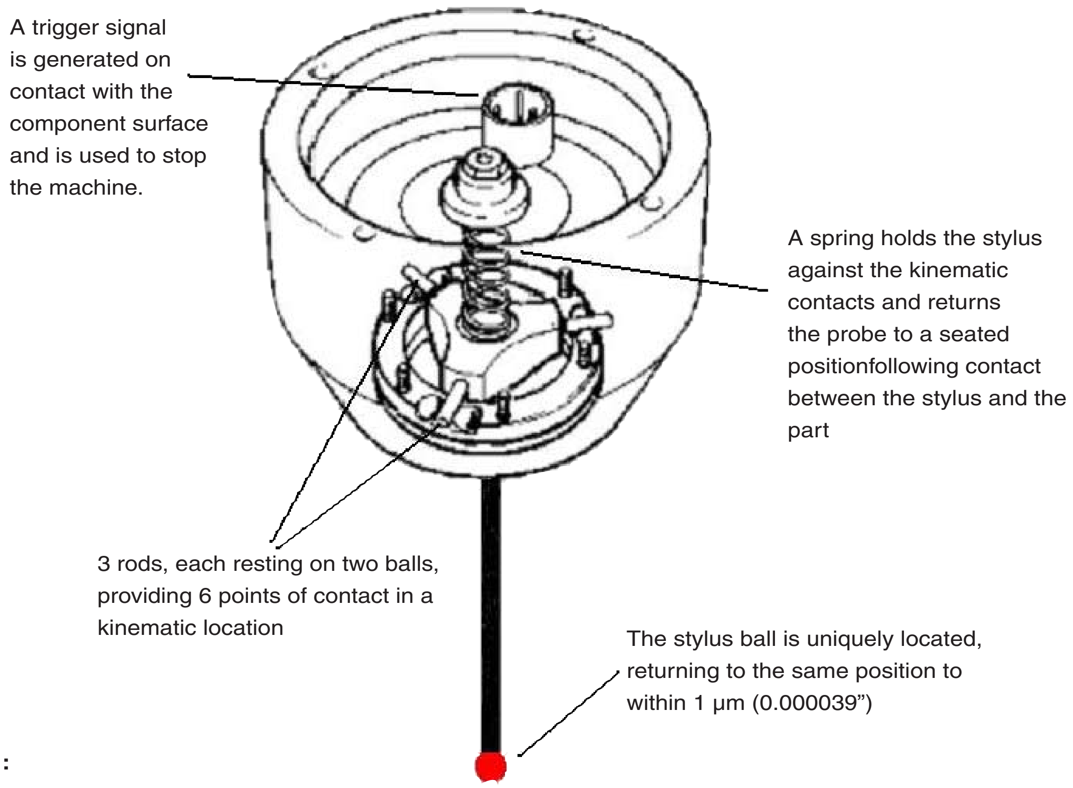


Figure 1:

Figure 2:

High force direction:

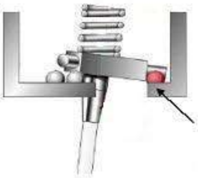


Figure 3:

Low force direction:

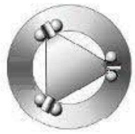


Figure 4: high and low force directions

The contact elements are made of tungsten carbide to ensure that the contact patches, where the material is elastically deformed under the force of the spring, are very small. An electrical circuit runs through the contacts, and it is the resistance through this circuit that is measured by the probe's electronics. When this resistance reaches a threshold, the probe's output is set to 'triggered'. Vitally, the balls and rods are still in contact when the trigger occurs, so that the stylus is in a defined position, providing repeatable measurement.

A number of factors affect kinematic touch probe measuring performance. From the point at which the stylus ball contacts the workpiece there is bending of the stylus prior to electrical triggering of the probe. This is known as pre-travel. Pre-travel will vary dependent on the length and stiffness of the stylus and the contact force (see figs. 2, 3 and 4). Pre-travel variation (PTV) - otherwise commonly known as lobing, probe measuring error or roundness measuring error - can affect measurement performance. In the case of Renishaw probes the sets of contacts form a triangular arrangement. Lobing occurs because the pivot distance varies depending on the direction in which the contact force acts in relation to the probe mechanism. Such lobing effects can be compensated by probe calibration.

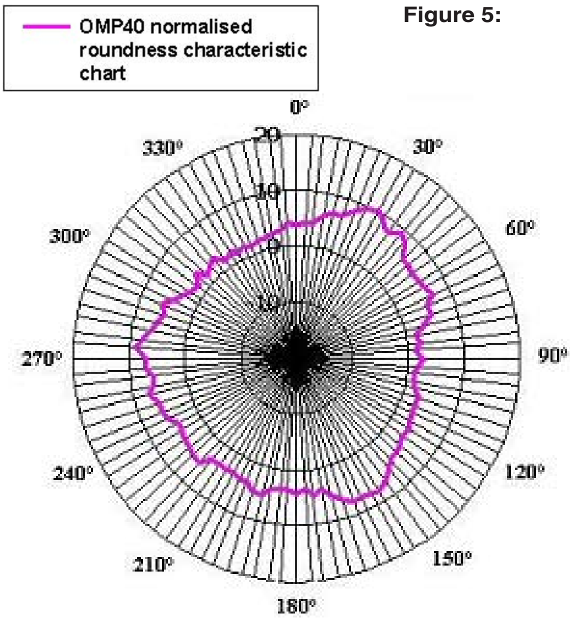
Consequently, there is a variation in the contact force – resulting in varied pre-travel distances. There are a number of other probe mechanisms that differ from the implementation described as the traditional probe. It is claimed that these systems offer low lobing or low measuring error in the XY plane. The Renishaw balls and rod mechanism in the OMP40, OMP60 and MP10 touch probes, has a typical PTV of 6 µm in the XY plane with a 50 mm stylus. **Figure 5** on the right shows a measuring test in a calibrated ring gauge run on a machine tool with 1 µm resolution position feedback. The maximum measuring error, including the machine, is 8.85 µm with a 50 mm standard ceramic stylus. The Renishaw approach has always been to have a small pre-travel, the suggestion that a three lobed pattern has larger measuring error is in fact not the general case.

The benefit of Renishaw's low pre-travel approach becomes evident when probing in 3D, such as the XZ and YZ planes, or a full 3D surface. This is because PTV also occurs in three dimensions, where there is a combination of XY and Z pre-travel effects. The pre-travel in the Z-axis of a Renishaw kinematic touch trigger probe is negligible, and as the XY pre-travel is also small the resulting error in 3D can approach that of the XY result. Also, probing against an inclined surface with a small pre-travel probe results in a trigger before the friction between the stylus ball and the surface is overcome.

In contrast, other types of probes with large mechanical pre-travel may generate forces prior to trigger that overcome the friction and cause skidding. Furthermore the larger difference in pre-travel between the XY plane and Z results in a larger 3D measuring error.

Figure 5 below shows a typical plot for the measurement of roundness of a calibrated ring gauge using an OMP40 kinematic probe.

Figure 5:



The three high force directions can be seen as the peak points of this plot. The maximum pre-travel variation in this case is around 8.85 µm (0.00035 in).

Calibration

Pre-travel itself need not result in a measurement error, since it can easily be compensated by probe calibration. A datum feature, of known size and position, is measured to establish the average pre-travel for the stylus concerned. Once this is complete, the key factor affecting measurement accuracy is the probe's repeatability.

However, there are some limitations. On complex parts, many probing directions may be needed. If the PTV value for the probe / stylus combination is sufficiently low, then its impact on the measurement accuracy may be acceptable. However, if this potential measurement error is unacceptably large, then it may be necessary to calibrate the probe for each direction in which it is to be used. This can be time consuming.

Strain gauge technology

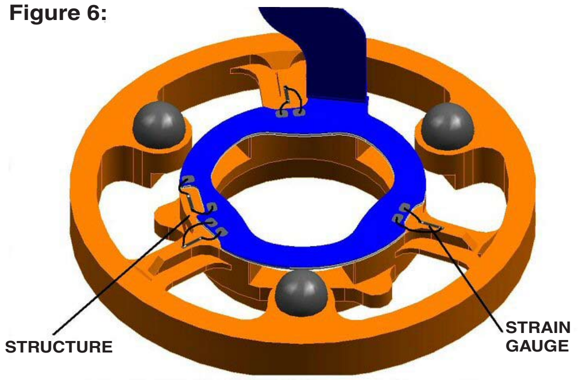
When looking for a technology to produce a high accuracy probe that could interface easily to a machine, the target is a lower pre-travel and hence lower PTV. Renishaw developed a new form of sensing technology that addressed the 3D measuring limitations of the kinematic resistive touch probe mechanism: silicon strain gauges. This has been made possible by ultra compact application-specific integrated circuit (ASIC) electronics and solid state sensing technology.

Although strain gauge touch probes still use a kinematic mechanism to retain the stylus, they do not use the resistance through the contact elements as the means to sense a trigger. Instead, a set of strain gauges is positioned on carefully designed webs in the probe structure beyond the kinematics. These gauges measure the contact force applied to the stylus and generate a trigger once the strain exceeds a threshold value in any direction. This provides a low trigger force, low pre-travel and low PTV.

The MP700 touch probe, introduced in 1995, was the first Renishaw machine tool probe to use strain gauges. It has brought to users all the benefits expected of the technology – improved repeatability, reduced pre-travel, and practical elimination of PTV. Such benefits manifest themselves in more accurate measurement, especially on 3D surfaces where many sensing directions are used, or in set-up, when approach vectors to the workpiece are not known

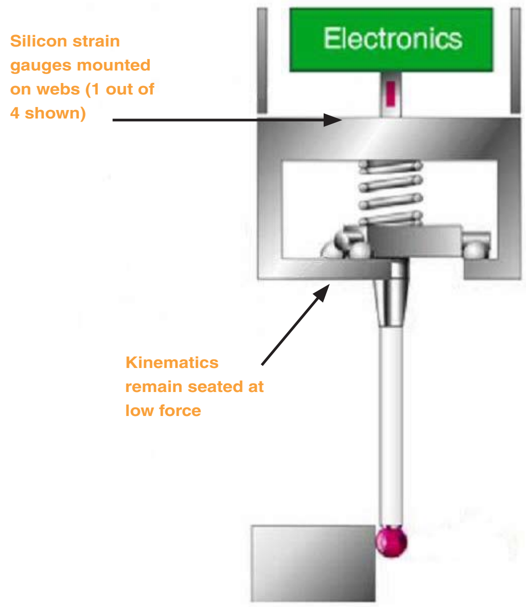
Figures 6 and 7 on the right shows schematics of a strain gauge touch probe. At low contact forces, the kinematics remain seated and the force is transmitted through them to the probe structure. The strain gauges are mounted on precision-manufactured webs designed to maximise the sensitivity of the probe, without compromising its robustness. They detect forces in the structure and their outputs are processed through electronics so that, once a force threshold is breached in any direction, a trigger signal is generated. This threshold force is typically a few grams – much lower than the trigger force on an equivalent mechanical probe.

Figure 6:



WIRES CARRY STRAIN SIGNAL BACK TO PROBE CIRCUITRY

Figure 7:



This approach to developing probes with low pre-travel can suggest to some that the probes would be susceptible to vibrations and shock, causing unexpected triggers. However, as an alternative to designing in large mechanical pre-travel and therefore losing measuring performance, Renishaw uses filtering circuitry inside the probe to establish whether the strains seen at the gauges are the result of a real and persistent deflection of the stylus, rather than a transient shock or vibration. To achieve this, a short and highly repeatable delay is inserted into the detection circuit from the instant the force threshold is first passed, after which a persistent and increasing force must be seen before a trigger is issued at the end of the delay period.

The OMP400 touch probe

The OMP400 is Renishaw's latest optical signal transmission machine tool touch probe. It features an improved version of the highly accurate strain gauge technology first seen in the MP700 within the same small dimensions as the award winning OMP40 kinematic touch probe. As a result, for the first time strain gauge accuracy is now available to small machine users.

The OMP400 touch probe offers extremely low pre-travel, and uses a novel and improved algorithm within the probes electronics to provide even lower PTV than that found in the industry leading MP700 touch probe. The benefits of this are that a simple probe calibration routine is all that is required to enable the product to be used in any direction. Combined with the extremely high level of repeatability enjoyed by the strain gauge touch probe, the OMP400 is the only viable solution for measurement of mould, die and other complex parts.

In addition, strain gauge technology brings the further benefits of a ten-fold increase in operational life over that enjoyed by traditional resistive probes. Furthermore an improved strain gauge structure within the probe increases the robustness of the product, ensuring it is well suited to the harsh environments experienced inside machine tools.

In kinematic resistive touch probes, the PTV increases with stylus length and this means that measurement performance requirements can limit the length of stylus that can be used. The OMP400 touch probe, with its lower and more consistent trigger forces, can provide superior measurement performance and support much longer styli. The OMP400 can support styli up to 200 mm in length, with only a small decrease in measurement performance.

Figure 8:

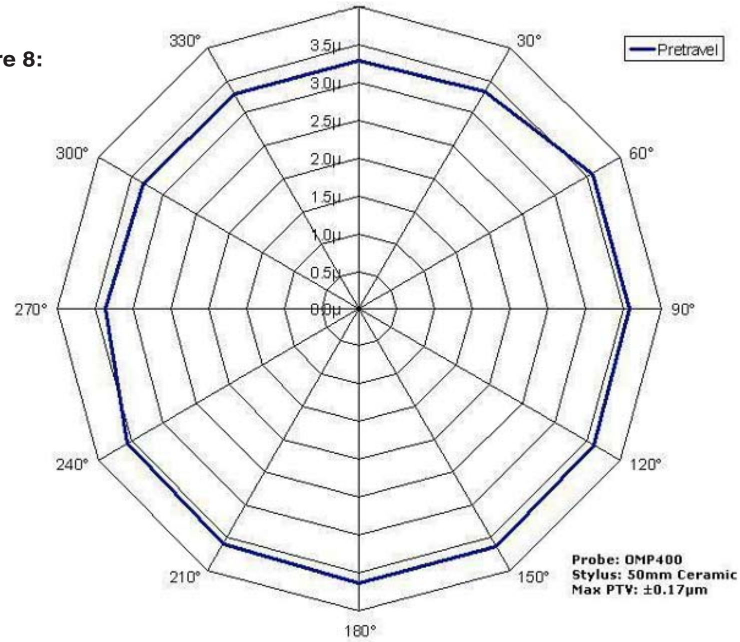


Figure 8 on the left shows a measuring test done on a Renishaw Probe Test Rig with 10 nm resolution, where 12 points are taken at 30° increments around a circle. The chart shows a typical PTV plot for an OMP400 touch probe, showing a low and almost uniform pre-travel in all directions. Using a 50 mm stylus, the PTV value in the XY plane is just 0.34 µm (0.000013 in), or roughly 90% less than the PTV value for a similarly sized kinematic touch probe. The OMP400 touch probe typically exhibits XYZ PTV values of less than 1 micron.

OMP400 probe	Stylus length			
	50 mm	100 mm	150 mm	200 mm
Repeatability Max 2 sigma in any direction of 12	0.25 µm	0.35 µm	0.50 µm	0.70 µm
2D (XY) lobing Max deviation from a ring gauge	± 0.25 µm	± 0.25 µm	± 0.40 µm	± 0.50 µm
3D (XYZ lobing) Max deviation from a known space	± 1.00 µm	± 1.75 µm	± 2.50 µm	± 3.50 µm